Universiti Teknologi MARA

DEVELOPMENT AND ANALYSIS OF EVOLUTIONARY PROGRAMMING FOR LEARNING MUSICAL NOTES

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Thesis submitted in fulfillment of the requirements for
Bachelor of Science (Hons) Intelligent System
Faculty of Information Technology And Quantitative Science

APRIL 2006

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DECLARATION

I certify that this thesis and the research to which it refers are the product of my own work and that any ideas or quotation from the work of other people, published or otherwise are fully acknowledged in accordance with the standard referring practices of the discipline.

APRIL 27, 2006

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ACKNOWLEDGEMENT

In the name of Allah, Most Gracious, Most Merciful

First and foremost, I would like to thank to Allah for the entire blessing He had given me upon completion this piece of work. There is myriad of people behind the scenes who have aided and supported my efforts during the completion of this project.

I am greatly indebted to my respectful advisor, Pn. Zaidah Ibrahim as my project supervisor for her invaluable advice, support, endless guidance, precious encouragement and resourceful ideas, which had helped me in completing this project.

A very special thanks goes to all my lecturers in FTMSK, course coordinator, Encik Mohd Zaki Zakaria, who throughout the years filled me up with all the knowledge. Not forgotten to all my fellow friends and colleagues for their valued information and sharing a good idea for this project especially for the final students of CS223.

My deepest appreciation also goes to my beloved family. Thanks for simply being there for me and sharing my joys and pains. To whom I failed to mention, who indirectly or directly contributed to this project, I thank you so much. Frankly, all of you mean so much to me.

ABSTRACT

This research is about applying three different types of Evolutionary Programming mutation operators onto musical notes which causing them to learn a small subset of children music notes. Research and study in Evolutionary Programming and its various types of mutations have been implemented. As a result, selected mutation types are obtained in order to perform this project. The musical notation that has been used is "Old McDonald Had A Farm" and it is represented using permutation encoding. The size of population, generations and mutation probability are usually random initialized by user. 48-bit strings of musical notes are randomly generated and it is evaluated by cost functions. The effect of random population size to the performance of each different Evolutionary Programming mutation type has been analyzed. From the experiments, it shows that hybrid mutation is better than one mutation type thus, is able to learn faster for overall populations.

TABLE CONTENTS

CONTENTS			PAGE
DECLARATION			ii
ACKNOWLEDGEMENT			iii
ABSTRACT			iv
LIST OF TABLES			viii
LIST OF FIGURES			ix
1.0	**CHAPTER 1: INTRODUCTION**		
	1.1	Introduction	1
	1.2	Problem Statement	1
	1.3	Objective of The Project	2
	1.4	Project Scope	3
	1.5	Significance of Study	3
	1.6	Summary	4
2.0	**CHAPTER 2: LITERATURE REVIEW**		
	2.1	Background of Evolutionary Programming	5
		2.1.1 Introduction	5
		2.1.2 What is EP?	6
	2.2	Mutation as the Main Operator	7
		2.2.1 Gaussian Mutation	7
		2.2.2 Cauchy Mutation	8
		2.2.3 Lévy Mutation	8

2.2.4 Single-point Mutation 8
2.3 Algorithm of EP 9
2.4 EP and Applications 10
2.5 Different Methodology / Approach to Solve Similar Problem 12
2.5.1 GA Solution for Evolving Musical Score 12
2.5.1[a] Major Steps to Evolve GA 13
2.5.2 RNN Solution for Music Composition 15
2.6 Summary 15

3.0 CHAPTER 3: METHODOLOGY

3.1 Project Methodology 16
3.1.1 Project Review 16
3.1.2 Knowledge Acquisition 18
3.1.3 Algorithm Adaptation 18
3.1.3[a] Steps in EP Algorithm 20
3.1.4 Implementation 25
3.1.5 Experimentation 26
3.1.6 Documentation 26
3.2 Software and Hardware Requirement 27
3.2.1 Software Requirement 27
3.2.2 Hardware Requirement 27
3.3 Summary 28

4.0 CHAPTER 4: ANALYSIS AND RESULT

4.1 Introduction 29
4.1.1 Effect of Random Initialization 29
4.1.2 Effect of Random Population Size 30
4.2 Summary 34

5.0 CHAPTER 5: CONCLUSION

5.1 Introduction 35

5.2 Conclusion 35

5.3 Recommendations 36

5.3.1 Prototype's Ability 36

5.3.2 Prototype's Weaknesses 36

5.3.3 Future Expansion 37

5.4 Summary 37

REFERENCES 38

APPENDICES

Appendix A: In-Progress Assessment 42

Appendix B: Old McDonald Had A Farm Musical Notes 43

Appendix C: Graphical User Interface 44

Appendix D: Source Code Snippets for Reciprocal Exchange 50

Appendix E: Source Code Snippets for Inversion Mutation 51

Appendix F: Source Code Snippets for Hybrid Mutation 53

List of tables

Table 4.1: The best fitness left after random population 31
Table 4.2: Performance of hybrid mutation on population 10, 20, 40, 50 32
Table 4.3: Performance of inversion mutation on population 10, 20, 40 33
Table 4.3: Performance of reciprocal exchange on population 30 33

List of figures

Figure 3.1: Methodology diagram for Learning Musical Notes 17

Figure 3.2: Flowchart for EP algorithm 19

Figure 3.3: Permutation Encoding 20

Figure 3.4: Before calculate the fitness 22

Figure 3.5: After calculate the fitness 22

Figure 3.6: Reciprocal exchange mutation 23

Figure 3.7: Inversion mutation 24

Figure 3.8: Hybrid mutation 24

Figure 4.1: The sample of user interface where user will have to enter the data 30

CHAPTER 1

INTRODUCTION

1.1 Introduction

Music has influenced man, and vice versa, since the dawn of civilization. Popular styles of music varied widely from culture to culture and from period to period. According to wikipedia, the encyclopedia, music is a human activity which involves structured and audible sounds, which is used for artistic or aesthetic, entertainment and many more. The beauty of music itself can conciliate someone when listen to it. According to (Dembo, 2002), music is a field that everyone can relate to and understand. Sometimes, it can be a type of agent to deliver what someone think about and feel about to others. In other words, music is used to express someone's feeling.

1.2 Problem Statement

There are many methods to compose the music. Conventionally, the ideas to create original music come from inspirations and perhaps, spontaneous by clicking the guitar, piano or bass fingerboard. Once the songwriter or composer feels it nice to be a song, it is generally notated on a piece of music sheet. Typically, the amount of time takes to compose a musical score depends on the type of music the songwriter wants to compose and how much there is to write but generally it takes a large amount of time.

From the interview with Mr. Rohaizad Redzuan, a young freelance composer, interviewee has stated that composers and engineers were already being use of computer in music composition in the late 60's. Some even have a musical keyboard linked to a computer which compiles the digital information into musical notation while they play. They may also program the composition in musical notation into the computer which can play back the piece. However, music composed by computerized system simply performing calculation and is thus performing strictly technical tasks of composition (Chowning, 1987). It can be defined or better understood by using an algorithm which can now write a computer program to test or learn the targeted score.

1.3 Objective of The Project

With the problems determined upon, researcher has chosen to implement a prototype for learning musical notes which learn and attempt to match the target scores. As Evolutionary Programming (EP) is not once applying to music, again, this motivation brings researcher to put into practice and at the same time connect music with computer science.

The underlying principles or objectives of this project are:

- To develop learning musical notes prototype which enables to learn a small set of simple musical notes by using EP.
- To analyze the performance of EP for learning musical notes with respect to 3 different types of EP mutation. They are reciprocal exchange mutation, inversion mutation and hybrid mutation.

1.4 Project Scope

This project focused on the simple children musical notes. The musical notation that has been used in this project is "Old McDonald Had A Farm". Besides, the project also includes an analysis on three selected of EP mutations types which has been stated in the previous section before.

1.5 Significance of Study

The successful of this learning musical notes will benefit and give the smart choice for young composers, music lovers and even music professionals. This group of people is the most target group as they are more exposed to the process of producing musical composition. With implementation of EP, it helps contribution and support in their creative work. Harmonic and collaboration of each musical bit, which produced by the random rhythms of population in the system, might be obtained and perhaps it can give some new inspiration to the composers.

Another important significance to the project is the use of EP might be able to facilitate for those who are interested in providing a better approach and solution in future implementation on many various problems. Aside from offering guideline to other researchers, this project may save their time in order to think which mutation types and rates are better to utilize in further prospect. Nevertheless, all type of methods are still depends on the specific problem area.

1.6 Summary

This chapter explains the overview of the project. Besides, the title of the project is defined. The title is Development and Analysis of Evolutionary for learning musical notes. Some basic problem has been acknowledged and objectives are derived based on this problem description. The scopes and significance regarding to the project have been explained as well.

CHAPTER 2

LITERATURE REVIEW

2.1 Background of Evolutionary Programming (EP)

2.1.1 Introduction

EP, which acronym to evolutionary programming, is one of the four major evolutionary algorithm paradigms. It was first introduced by Lawrence J. Fogel in 1960 and was later continued by his son David Fogel. The common propose underlying behind the idea is to use simulated evolution as a learning process aiming to generate artificial intelligence (AI) (http://en.wikipedia.org/wiki/Evolutionary_programming).

In this simulation, Fogel offered methods of simulating through the use of phenotype process. The process is more concerns on the parent offspring behavioral link or relations instead of the genetic link (Fogel, 1999). It emphasizes on the use of mutation operators that will generate a continuous range of behavioral diversity with a strong correlation between parents and offspring.

2.1.2 What is EP?

EP is the study of programs meant to simulate and predict evolutionary solution using problems that are usually based on real-world situations. It is a simulation based on the way genes are maintained through the process of evolution.

Inspired by the biological evolutionary, EP is proposed as an approach to AI. There are numerous applications that EP has been implemented. For example, scientists have used EP techniques in order to find solutions to very complex problem. These evolving programs find good solutions to these complex problems (Timothy, 1987).

The biggest advantage of EP is it can solve problems that human are unable to solve or come up with the solutions better than any human solution (Mathew, 2000). The primary difference between EP and the other approaches, such as Genetic Algorithm (GA), Genetic Programming (GP) and Evolution Strategy (ES), is that no exchange (crossover) of material between individuals in the population is made.

In GA, the crossover operator plays the major role and the mutation is always seen as an assistant operator. In EP, however, the mutation is treated as the main operator and it does not involve crossover.

2.2 Mutation as the Main Operator

As mentioned previously, mutation act as the major operator in EP. It represents a random change in the one or more genes. It also may lead to a significant improvement in fitness (Negnevitsky, 2005). Fitness or evaluation function is used to measure the performance of chromosome for the problem to be solved.

Besides, mutation also enables the EP to maintain diversity from one generation of a population of chromosomes to the next. Regarding to (Eiben & Schoenauer, 2005), this operator may conceive depending upon the details of the problem.

There was various mutation operators have been employed from the previous research. Gaussian, Cauchy, Lévy and Single-point mutation were the four different mutations that have been presented in the last decade. Mostly, all these mutations have been widely applied successfully in solving numerical optimization problem.

2.2.1 Gaussian Mutation

Gaussian mutation is the classical mutation used in Conventional EP (CEP). In contrast, this type of mutation cannot solve multi-modal functions very well.

2.2.2 Cauchy Mutation

Cauchy mutation was proposed as a Fast EP (FEP). It converges faster to a better solution than CEP on many multivariate functions. On the other hand, it is less efficient on some unimodal functions.

2.2.3 Lévy Mutation

EP using Lévy mutation (LEP) is more flexible than CEP because of its scaling parameter. However, it still cannot solve all test functions very well if using a fixed parameter. Besides, it is also difficult to determine the optimal for a given problem.

2.2.4 Single-point Mutation

The Single-point mutation EP (SPMEP) searches only one component of solutions in each generation and its deviation follows a fixed mutation scheme. SPMEP is claimed to be superior to CEP and FEP on many multimodal and high-dimensional function. However, it is worse than CEP on low-dimensional function with few local optima.

Due to (Dong et. al., 1991), each mutation operator is suitable for solving some types problems but may not be efficient in solving other types.

2.3 Algorithm of EP

Algorithm is a procedure or set of rules for solving a problem especially by computer. Mostly, the general scheme of an EP algorithm is shown below (http://www.faqs.org/faqs/ai-faq/genetic/part2/section-3.html).

```
Algorithm EP is
        t : = 0;
        initpopulation P(t);
        evaluate P(t);
        WHILE not done DO
                P'(t) : = mutate P(t);
                evaluate P'(t);
                P(t+1) : = survive P(t), P'(t);
                t : = t+1;
        od
end EP
```

Basically, algorithm of EP starts with an initial time, t = 0 followed by initialization of individual, P(t). Initialization of individual is randomly generated. Then, fitness of all the initial individual of population is evaluated followed by perturb (mutation) the whole population stochastically, P'(t) = mutate P(t). Afterward, new fitness, again, is calculated and the survivors from actual fitness are selected stochastically. The algorithm will extend until the best individual is good enough.

2.4 EP and Applications

There are many different applications has been applied in EP approach. For instance, in machine learning and prediction problem (Fogel, 1999), optimization (Yao et. al., 1999), biological study, AI games (Torahtein, 1993), (Dong et. al., 1991) and economic dispatch (Effirul, 2003).

Machine learning is based on computational models of natural selection and genetics. (Fogel et. al., 1966) have stated through their best selling book, Artificial Intelligence through Simulated Evolution, that a mathematical automaton is one of the machine learning applications which has been solved by EP. This machine is used to predict a binary time series.

Besides, EP is a useful method of many numerical and combinatorial optimizations. It is practically used when other techniques such as gradient descent and analytical discovery are not possible (Beasley, 2004). Regarding to (Dong et. al., 1991), (Back et. al., 1993) and (Yao et. al., 1999), EP is very similar to ES when need to solve function optimization problem. The similarity extends to the use of self-adaptive method for determining the appropriate mutations to be used.

Furthermore, this EP algorithm is also applied in the study of evolutionary science in Biology (Torahtein, 1993). By creating and using different algorithms, scientists have come up with more precise information of how and why creatures evolve the way they have and have predicted the way they evolve.

Many aspects of AI in gaming have been implemented in EP too (Torahtein, 1993). The mixed or hybrid mutations have been used and regarded as players or operators in an artificial evolutionary game. According to (Dong et. al., 1991), this operators are used to generate offspring and adjust the strategy for better survive. In other word, EP it is used to simulate civilization in AI game.

Economic Dispatch is another application that presents EP. Economic dispatch is the problem of determining the active power to be generated by an active unit given a demand at a minimum cost. Regarding to (Effirul, 2003), EP approach enables to help the power system management in providing a better approach and solutions for economic dispatch problems.

2.5 Different Methodologies / Approach to Solve Similar Problem

2.5.1 GA Solution for Evolving Musical Scores

Research on musical scores using GA as a method had been attempted before. GAs have proven to be efficient search approach especially when dealing with problems with very large search spaces (Holland, Goldberg, 1989). This reason, coupled with their ability to provide multiple solution which is often what is needed in creative domain, makes them a good choice for solving musical scores.

Previous researcher has presented some “event” in a song by using binary encoding. Event can include nearly anything in music such as notes, rest, time signatures, repeat sign, fermatas and so forth. Referring to (Dembo, 2002), binary encoding seems to be possible to differentiate between each type of notation.

Dembo also stated in his research that each chromosome was composed of 30-bits string (number of musical notes). Each of 30-bit string or genotype was randomly generated to match a target song. Each of the string was evaluated by the cost functions. The total production costs will become the fitness value of each chromosome.

The chromosome was then being selected to crossover with another chromosome at randomly chosen point. The selection of the chromosome was based on the fitness ratio by the tournament selection. 0.8 rates for crossover and 0.01 rates for mutation were chosen in the research. According to (Dembo, 2002), a value of 0.8 for crossover probability generally produces good result and mutation for one bit almost assured.

Besides, 50 as the population sizes and 50 generations were significant to be used for evolving musical scores (Dembo, 2002). Meanwhile, the termination criterion was chosen at the arrival at generation 51. The results were deemed after the rise of a perfect individual.

2.5.1.1 **Major Steps to Evolve GA** (Davis, 1991; Mitchell, 1996).

Step 1:

Represent the problem variable domain as a chromosome of a fixed length, choose the size of a chromosome population *N*, the crossover probability *pc* and the mutation probability *pm*.

Step 2:

Define a fitness function to measure the performance, or fitness, of an individual chromosome in the problem domain. The fitness function establishes the basis for selecting chromosomes that will be mated during reproduction.

Step 3:

Randomly generate an initial population of chromosomes of size *N*:

$$x1, x2, \ldots, xN$$

Step 4:

Calculate the fitness of each individual chromosome:

$$f(x1), f(x2), \ldots, f(xN)$$

Step 5:

Select a pair of chromosomes for mating from the current population. Parent chromosomes are selected with a probability related to their fitness.

Step 6:

Create a pair of offspring chromosomes by applying the genetic operators' – crossover and mutation.

Step 7:

Place the created offspring chromosomes in the new population.

Step 8:

Repeat *Step 5* until the size of the new chromosome population becomes equal to the size of the initial population, *N*.

Step 9:

Replace the initial (parent) chromosome population with the new (offspring) population.

Step 10:

Go to *Step 4*, and repeat the process until the termination criterion is satisfied.